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Evidence-based, cost-effective management of acute appendicitis: An algorithm of the Journal of Trauma and Acute Care Surgery emergency general surgery algorithms work group

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THE EVALUATION OF THE PATIENT WITH ACUTE ABDOMINAL PAIN: HISTORY AND PHYSICAL AND INITIAL LABORATORIES

Evaluation of the patient with abdominal pain begins with a thorough history and physical examination (Fig. 1). Patients typically present with 12 to 24 hours of mid-abdominal pain, which may migrate to the right lower quadrant. In the early course of appendicitis, the physical examination may reveal nonlocalizing, mid-abdominal pain without peritoneal irritation. Additional symptoms may include loss of appetite, abdominal distention, nausea, vomiting, malaise, obstipation, fever, and chills. Patients may also have certain physical signs associated with appendicitis. The psoas sign is an irritation of the iliopsoas muscle in the abdomen, a classic finding of acute appendicitis, which can be elicited by performing passive extension of the right hip with the patient laying on their left side. The Rovsing's sign can also be seen in acute appendicitis and is observed when deep palpation of the left lower quadrant elicits pain in the right lower quadrant. Patients presenting later in the course of the disease process may develop peritoneal inflammation with localized guarding and rebound tenderness adjacent to the appendix in the right lower quadrant.[1]

Standard laboratory tests should include a complete blood count, urine analysis, and routine chemistry if the patient requires further imaging or operative management. It is important to note that white blood count may not be elevated in early acute appendicitis.[2] A urine analysis would assist in ruling out other diagnoses, such as urinary tract infection, pyelonephritis, or renal stones. A pregnancy test is mandatory for women of childbearing age.

CALCULATION OF SCORING SYSTEMS FOR APPENDICITIS

Utilizing a scoring system such as the Appendicitis Scoring score (Fig. 2) may contribute to the accuracy of clinical decision-making and support shared decision-making by identifying patients at low risk of appendicitis.[3]

The Alvarado score (Table 1) is the most commonly used scoring system for predicting the likelihood of acute appendicitis. If a patient scores 1 to 4, the risk of appendicitis drops to 33%. If a patient scores >5, the risk of acute appendicitis is 66% or greater. The Alvarado score can be used to select which patients will proceed for confirmational imaging.[4,5] In many current practice settings, abdominal imaging will have been obtained prior to surgical consultation.[6,7]

Appendicitis inflammatory response score (Fig. 3) has been shown to perform best in terms of sensitivity, specificity area under the curve values, and usability but has been validated in only a small number of studies. The original Alvarado score outperformed the modified Alvarado score across all three criteria (sensitivity, specificity, and area under the curve values).

IMAGING OF THE PATIENT SUSPECTED OF APPENDICITIS

Ultrasound Versus Computed Tomography Scan

Ultrasound (US) has been used to evaluate patients suspected of acute appendicitis and has an 85% to 90% positive predictive value with an appendiceal diameter greater than 9 to 10 mm.[8] It does not use radiation energy, is repeatable, and is safe for pregnant women. It can also demonstrate other pelvic pathology in women.[9,10] Ultrasound is frequently used in pediatric patients

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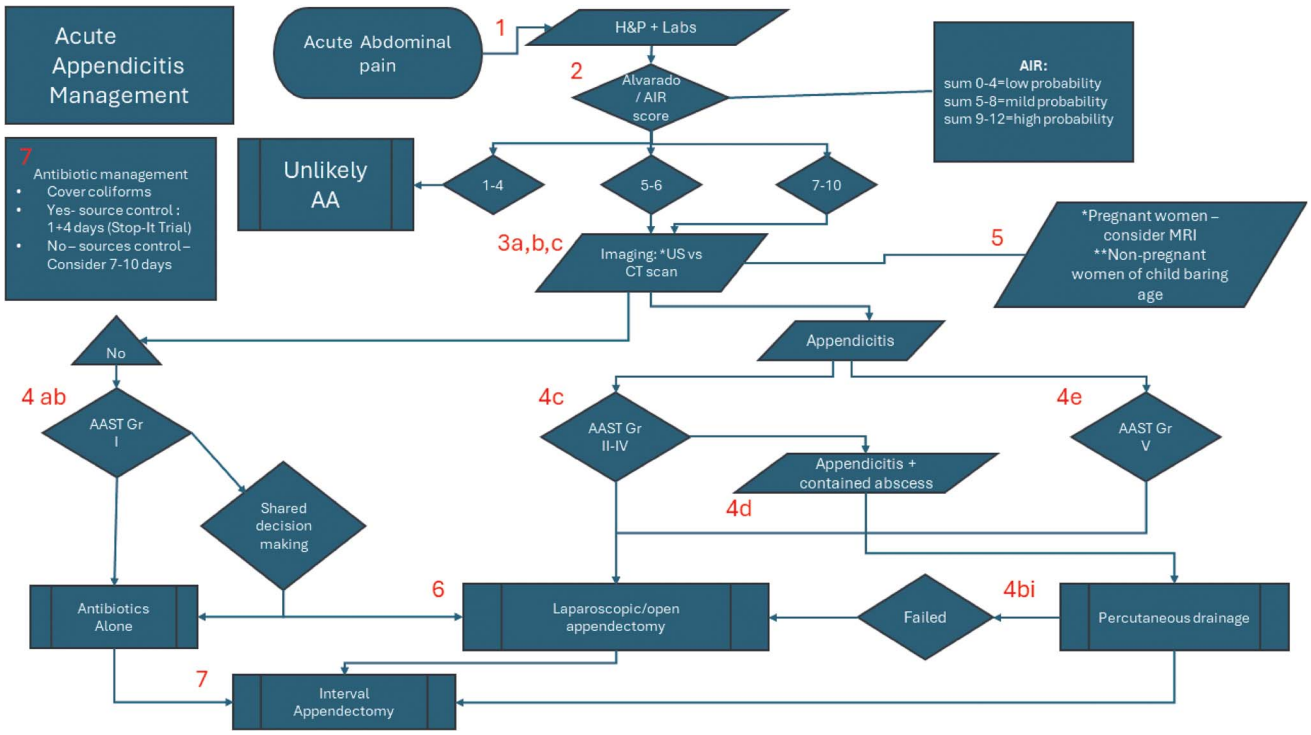

Figure 1. Acute appendicitis management.

and is favored as an initial study in small children. The utility of US is less well documented in the adult population.

Computed tomography scan with contrast has been the standard for imaging the abdomen when searching for acute pathology and is used with increasing frequency in the general diagnosis of abdominal pain, especially by nonsurgeons. It provides a high degree of sensitivity and specificity for the diagnosis of acute appendicitis but has the potential to identify radiographic abnormalities of the appendix that are not clinically relevant. Computed tomography imaging should always be interpreted in the context of clinical history and physical examination. Computed tomography can also demonstrate an appendiceal fecalith, periappendiceal fluid collection, or an abscess, findings that may be of importance in clinical decision-making. The sensitivity, specificity, positive, and negative predictive values of computed tomography (CT) scans based on pathology results were 87.9%, 81.8%, 94.7%, and 79.3%, respectively, in patients with low clinical suspicion.[11]

In many circumstances, the position of the appendix within the abdomen and its relation to the cecum will be demonstrated.[12]

Women

Childbearing Age

Pelvic pathology must be ruled out when suspecting acute appendicitis in women of childbearing age. A urine analysis may demonstrate urinary tract infection or potential kidney stones. An US or CT scan may show an adnexal tubo-ovarian abscess or ectopic pregnancy.[13]

Pregnant Women

Ultrasound is the primary imaging modality to assess abdominal pain and make the diagnosis of acute appendicitis in pregnant patients, although magnetic resonance imaging is being used with increasing frequency if US findings are not diagnostic. A CT scan should be considered if a patient is acutely ill, and the diagnosis is still in question.[11,14–19] Alternatively, if CT scan does not clearly demonstrate acute appendicitis in the pregnant patient, magnetic resonance imaging has been shown to have a high sensitivity and negative predictive value of 100% in some studies.[20]

MANAGEMENT OF PATIENTS WITH ACUTE APPENDICITIS (AMERICAN ASSOCIATION FOR THE SURGERY OF TRAUMA ACUTE APPENDICITIS SEVERITY OF ILLNESS)

(Additional classification of appendicitis commonly used are as follows: uncomplicated appendicitis [nonperforated, no abscess, or phlegmon] or complicated appendicitis [perforated appendicitis, periappendicular abscess or peritonitis, defined as acute inflammation of the peritoneum secondary to infection of the appendix].) (Fig. 4)[21]

a. American Association for the Surgery of Trauma Grade I (mild) represents mild appendicitis without significant inflammation (uncomplicated appendicitis). The current literature demonstrates that nonoperative management with antibiotics and pain control is noninferior to surgical treatment.[22,23] Although early appendectomy is likely the most expeditious treatment, patient-centered concerns such as a desire to avoid surgery or timing of surgery should be discussed and considered as part of shared decision-making. A publicly available decision support tool called AppyOrNot (AppyOrNot.org) provides an educational video to assist patient decision-making. The presence of a fecalith does not preclude nonoperative management, although the likelihood of requiring additional

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Adult Appendicitis Score (AAS): score ≤10 low risk of appendicitis, score 11–15 intermediate risk of appendicitis, and score ≥16 high risk of appendicitis.

		Score
Symptoms and findings		
Pain in RLQ		2
Pain relocation		2
RLQ tenderness	Women, aged 16–49 years	1
	All other patients	3
Guarding	Mild	2
	Moderate or severe	4
Laboratory tests		
Blood leukocyte count ($\times 10^9$)	≥7.2 and <10.9	1
	≥10.9 and <14.0	2
	≥14.0	3
Proportion of neutrophils (%)	≥62 and <75	2
	≥75 and <83	3
	≥83	4
CRP (mg/L), symptoms <24 h	≥4 and <11	2
	≥11 and <25	3
	≥25 and <83	5
	≥83	1
CRP (mg/L), symptoms >24 h	≥12 and <53	2
	≥53 and <152	2
	≥152	1

RLQ: the right lower abdominal quadrant; CRP: C-reactive protein.
AAS calculator: www.appendicitisscore.com.

Figure 2. Adult appendicitis score. Adapted from Bhangu,[3] published under Creative Commons CC-BY-NC-ND license.

procedures is higher. The report of long-term outcomes from the Comparison of outcomes of antibiotic drugs and appendectomy trial confirmed that the hazard ratio for appendectomy among patients with an appendicolith compared with those without an appendicolith was 2.9 within 48 hours but was not difference thereafter from 48 hours to 30 days (Hazard ratio, 1.4; 95% confidence interval, 0.8–2.4) and from 31 days to 2 years (Hazard ratio, 1.1; 95% confidence interval, 0.8–1.6).[24–28]

b. American Association for the Surgery of Trauma Grades II to IV (moderate to severe) (complicated appendicitis) represents increasing degrees of inflammation, development of periappendiceal fluid collections, abscess formation, progression of gangrenous appendicitis, and peritonitis. The decision between initial appendectomy versus initial nonoperative management is complex, as patients with larger phlegmon and more advanced inflammatory changes involving surrounding organs may benefit from initial nonoperative management. Decision-making should be individualized based on patient factors and surgeon experience. Some patients presenting with sepsis will require preoperative fluid resuscitation in addition to early antibiotics. Minimally invasive approaches to appendectomy have become the procedure of choice. If not available, an open appendectomy is indicated.[29–33]

i. Patients presenting with perforated appendicitis and a large inflammatory tumor (phlegmon) with abscess are best managed with early broad-spectrum antibiotics and percutaneous drainage (80% successful) for source control. A surgical approach to abscess drainage, either by minimally invasive or open technique, may be indicated if drainage and antibiotics fail to resolve the infection.[34]

c. American Association for the Surgery of Trauma Grade V (most severe) represents the most severe presentation of free perforation due to acute appendicitis in the abdominal cavity. Patients are commonly present in septic shock and Sepsis 3 guidelines for resuscitation should be followed.[35] These are surgical emergencies. Treatment consists of

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TABLE 1. Alvarado Score (Adapted From Ohle et al.[4])

Alvarado Score		
Variable	**Clinical Findings**	**Score**
Symptoms	Migratory RIF pain	1
	Anorexia	1
	Nausea and vomiting	1
Signs	Tenderness RIF	2
	Rebound tenderness	1
	Elevated temperature	1
Laboratory	Leukocytosis	2
	Left shift (bandemia)	1
Total score		

RIF, right iliac fossa.

resuscitation, administration of broad-spectrum antibiotics, pharmacological cardiovascular support, and emergent operative management.[36]

MANAGEMENT OF COMPLICATED APPENDICITIS DURING PREGNANCY

In this retrospective cohort study of 8,087 pregnant women with complicated appendicitis using National Inpatient Sample data (January 2003 to September 2015), immediate appendectomy was associated with lower odds of infectious complications, including amniotic infection and sepsis, compared with successful and unsuccessful nonoperative management. When nonoperative management failed and required delayed operation, it was associated with significantly higher odds of preterm labor, preterm delivery, or abortion. These findings suggest that immediate operation may be the preferred management strategy for complicated appendicitis among pregnant women.[37]

TIMING OF APPENDECTOMY AND RISK OF APPENDICEAL PERFORATION

With early initiation of early empiric intravenous systemic antibiotic therapy for acute uncomplicated appendicitis, appendiceal perforation prior to surgical intervention for uncomplicated appendicitis is now rare. The PERFECT open-label multicenter randomized trial compared appendectomies scheduled within 8 or 24 hours in adult patients (n = 1,803) with predicted uncomplicated acute appendicitis. The appendiceal perforation rate was similar (8% vs. 9%), and no significant differences in complication rates (7% vs. 6%) were found, with no mortality differences noted. A meta-analysis comparison (15 studies, n = 33,596) of daytime versus nighttime appendectomy reported no differences in postoperative mortality or complication rates, but the conversion to laparotomy was almost twofold higher among patients who underwent appendectomy during nighttime. These data support postponing night-time appendectomy to daytime if possible.[38,39]

ANTIBIOTIC MANAGEMENT

In the setting of operative management of American Association for the Surgery of Trauma (AAST) Grade I or II, a single perioperative dose of antibiotics should be sufficient. In AAST Grade III or higher, perioperative antibiotic management should be dictated by source control. Once source control is obtained, a perioperative dose plus four additional days should be sufficient to align with the STOP-IT trial. In the setting of a periappendiceal abscess managed by percutaneous drainage or phlegmon, an initial course of 7 to 10 days of antibiotics is

Appendicitis Inflammatory Response (AIR) score, 0–12 points

From: Validation of the Appendicitis Inflammatory Response (AIR) Score

Item	Scoring point
Vomiting	1
Pain in right inferior fossa	1
Rebound tenderness or muscular defence	
Light	1
Medium	2
Strong	3
Body temperature ≥38.5 °C	1
White blood cell count	
10.0–14.9 * 109/L	1
≥15.0 * 109/L	2
Proportion polymorphonuclear leucocytes	
70–84%	1
≥85%	2
C-reactive protein concentration	
10–49 mg/L	1
≥50 mg/L	2

Seven variables are assessed and scored accordingly. After the revision proposed in this report a score 0–3 points suggest low probability, a score 4–8 medium probability and a score 9–12 high probability

Figure 3. Appendicitis inflammatory response. Reproduced without changes from Andersson et al.,[6] published under Creative Commons Attribution 4.0 International License.

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American Association for the Surgery of Trauma (AAST) grading system for appendicitis					
Grade	Description	Clinical Criteria	Image Criteria	Operative Criteria	Pathologic Criteria
Grade I	Acutely inflamed appendix that is intact	Pain, leukocytosis and right lower quadrant (RLQ) tenderness	Inflammatory changes localized to appendix +/- appendiceal dilation +/- contrast non-filling	Acutely inflamed appendix, intact	Presence of neutrophils at the base of crypts, submucosa +/- in muscular wal
Grade II	Gangrenous appendix, intact	Pain, leukocytosis and RLQ tenderness	Appendiceal wall necrosis with contrast nonenhancement +/- air in appendiceal wall	Gangrenous appendix, intact	Mucosa and muscular wall digestion; not identifiable on hematoxylin and eosin stain (H & E
Grade III	Perforated appendix with local contamination	Pain, leukocytosis and RLQ tenderness	Above with local periappendiceal fluid +/- contrast extravasation	Above, with evidence of local contamination	Gross perforation or focal dissolution of muscular wall
Grade IIV	Perforated appendix with periappendiceal phlegmon or abscess	Pain, leukocytosis and RLQ tenderness; may have palpable mass	Regional soft tissue inflammatory changes, phlegmon or abscess	Above, with abscess or phlegmon in region of appendix	Gross perforation
Grade V	Perforated appendix with generalized peritonitis	Generalized peritonitis	Diffuse abdominal or pelvic inflammatory changes +/- free intraperitoneal fluid or air	Above, with addition of generalized purulent contamination away from appendix	Gross perforation
Reference: https://www.aast.org/resources-detail/egs					

Figure 4. American Association for the Surgery of Trauma — Appendicitis Grades.[21] Reused with permission from the American Association for the Surgery of Trauma.

generally chosen, although there is little evidence to support the practice. In the absence of clinical improvement, additional imaging is warranted.[40–42]

INTERVAL APPENDECTOMY AFTER NONOPERATIVE MANAGEMENT WITH ANTIBIOTICS

In patients treated with antibiotics for *uncomplicated* appendicitis, interval appendectomy is commonly considered for patients with recurrent symptoms or recurrent disease. Appendiceal neoplasm is rare in patients with uncomplicated appendicitis treated with antibiotics. In a review of 4,962 patients with appendicitis (38% complicated, 62% uncomplicated) enrolled in 4 comparative studies, the overall incidence rate of neoplasm in the uncomplicated cohort was 1.49%.[43]

Importantly, in patients with previous *complicated* appendicitis treated nonoperatively, a colonoscopy (4–6 weeks after resolution) and an interval appendectomy should be performed (recommended by 2024 SAGES Guideline), as the incidence of appendicular neoplasm is high (3–17%, pooled prevalence 11%) in adult patients with complicated appendicitis. Appendiceal mucinous neoplasms occurred in 43%, adenocarcinoma in 29%, neuroendocrine neoplasm in 21%, goblet cell carcinoma in 13%, and adenoma or serrated lesions in 20% of cases.[44–47] American Association for the Surgery of Trauma Grades II to IV may require interval appendectomy, but AAST Grade I may not absolutely require interval appendectomy unless symptoms recurred.

AUTHORSHIP

J.J.D. and R.C. contributed in the conception and study design. All authors contributed in the literature review. All authors contributed in the drafting of the manuscript. All authors contributed in the critical revisions.

DISCLOSURE

Conflict of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/E245).

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